

Multivariate Approaches for Dynamic Soil Property Characterization in Some Southeastern U.S. Coastal Plain Map Units

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ABSTRACT

The National Cooperative Soil Survey is investigating methods for integrating management dependent soil property assessment into the program. These management dependent properties provide information for both dynamic soil quality evaluation and improving map unit interpretations. Multivariate techniques can be used to both facilitate selection of critical measures of soil change and estimate soil property variation. The southeastern U.S. once supported approximately 90 million acres of longleaf pine (*Pinus palustris* Miller) ecosystem, but less than 3% remains today. Using this ecosystem as a reference, our objectives were to use multivariate techniques to evaluate management effects on near-surface soil properties in select ecosystems of the southeastern Coastal Plain to: 1) determine key indicators of soil condition, 2) assess relationships between taxonomic-based soil map units and land management systems, and 3) develop pedotransfer functions for estimating map unit soil hydraulic properties from more easily measured dynamic soil properties. Analyses included multiple regression, principle component analysis, and multivariate clustering. Sites in the Tallahassee Hills ecoregion of south Georgia, representing three soil map units (soils with sandy epipedons and loamy to clayey kandic horizons), were selected in each of three management systems for comparison of near surface (0-30 cm) soil properties. Several near-surface (0-30 cm) soil chemical, physical, and biological properties were measured. Principal component analysis indicated 80% of near-surface soil property variability was explained by exchangeable bases, C pools, and hydraulic soil properties. Therefore, these properties are suggested as soil change indicators in these settings. Clustering of normalized data indicated near-surface soil properties were more similar by management than by soil map unit, suggesting the importance of addressing land management history for soil interpretation. Pedotransfer functions described >90 % of the hydraulic property variability, and thus adequately characterized hydraulic properties as a function of management for these soil map units. More intensive cultivation generally reduced the inherent variability of investigated near-surface soil properties. Near-surface soil hydraulic properties provide the basis for several important soil survey interpretations, but are time-consuming and laborious to measure. It is suggested multivariate techniques can play a role in their estimation.

INTRODUCTION

Research is needed to incorporate functional properties of soil change with soil survey and natural resource planning (Tugel et al., 2005). Understanding relationships between management dependent and inherent soil properties facilitates soil survey interpretations. Past studies have used multivariate approaches to characterize dynamic soil properties, and pedotransfer functions have been developed to estimate soil hydraulic properties from more easily obtained soil properties. The inclusion of undisturbed ecosystems (e.g., native Longleaf-wiregrass systems) in soil dynamic property assessment has been rare in the Southeastern U.S.

MATERIALS AND METHODS

Study sites were selected in Thomas County, Georgia. Soils in this study represented well-drained, acid, upland consociations common to the Southeastern Coastal Plain. Three soil map units were sampled including: 1) Faceville loamy sand, 0-5 % slopes (fine, kaolinitic, thermic Typic Kandiudults), 2) Orangeburg loamy sand, 0-5 % slopes (fine-loamy, kaolinitic, thermic Typic Kandiudults), and 3) Lucy loamy sand, 0-5 % slopes (loamy, kaolinitic, thermic Arenic Kandiudults). Each soil consociation was replicated in three management systems (n=9). Longleaf management consisted of mature, multi-aged longleaf pine forests with native groundcover (e.g., wiregrass (*Aristida stricta* Michx.)). Planted pine sites consisted of a 22-year old planted slash pine stand in the first rotation with infrequent fire and mechanical treatment. Row crop sites had generally been in cropping rotations of corn (*Zea mays*)-peanut (*Arachis hypogaea* L.)-soybean (*Glycine max* (L.) Merr.) under conventional tillage management (30-35 years).

Composite soil samples (0-5, 5-15, 15-30 cm) representing 9 sites were sampled in 2006/2007. Measured properties included particle size distribution (<2 mm), cation exchange capacity (CEC), effective CEC, NH₄OAc exchangeable bases (Ca, Mg, K, Na), percent base saturation, KCl extractable Al, Mehlich extractable P, total organic C and N, particulate organic matter C and N (POMC and POMN, respectively), mineral associated C and N, potentially mineralizable C and N, microbial biomass C, bulk density, and water stable aggregates (0-5 cm). *In situ* measurements included surface infiltration rate (IR), saturated hydraulic conductivity (15 cm), and soil strength (SS) (0-30 cm).

Principal component analysis (PCA) and multivariate clustering utilized normalized data (0-100) developed from a weighted average (0-30 cm) of data from three depths (0-5, 5-15, and 15-30 cm). Single-linkage Euclidean distance clustering was performed for measured soil properties, and a dendrogram was created for similarity assessment among sites. Stepwise linear regression was used to develop pedotransfer functions within soil map units (as a function of management) to estimate soil hydraulic properties.

RESULTS AND DISCUSSION

Principal component analysis indicated four components explained 86% of the near-surface soil property, and suggested exchangeable bases, bulk density, C and N pools, CEC, IR, plant available water, and SS are important indicators of soil change (data not shown). The cluster dendrogram indicates that management results in more similarity among the measured dynamic near-surface soil properties (0-30 cm) as compared to taxonomic based survey groupings (Figure 1). Mechanical disturbance reduced the variability of near-surface soil properties across soil map units.

Pedotransfer functions were developed to estimate hydraulic properties (Table 1). Bulk density and SS significantly described the variability of IR and saturated hydraulic conductivity in the Faceville and Orangeburg map units, whereas water dispersible clay described relatively more variability in the Lucy map unit. Higher bulk density, soil strength, and wdc results in lower surface horizon permeability in these soil systems.

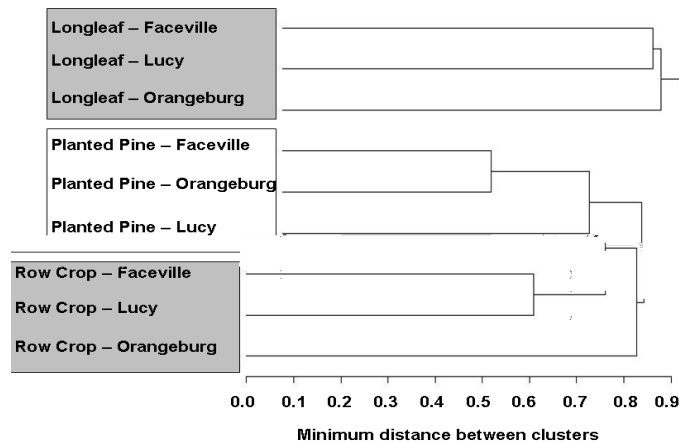


Figure 1. Multivariate clustering dendrogram for near-surface (0-30 cm) soil properties for three map units in the Southeastern U.S. Coastal Plain.

CONCLUSIONS

Multivariate statistical techniques can be useful tools for characterizing and estimating near-surface dynamic soil properties. Our results indicate that management induces similarity in near-surface dynamic soil properties between similar map units. In addition, pedotransfer functions can be developed to help estimate near-surface soil hydraulic properties using more readily measured soil properties. Thus, data and models developed from sampling and characterization of near-surface, management dependent properties of benchmark soils can likely be applied to similar soils for improved map unit characterization and interpretation.

Table 1. Regression model parameters relating soil hydraulic properties to near-surface soil properties for three soil map units in the Georgia Coastal Plain (variables and abbreviations described in methods).

Consociation	Dependent variable	Significant Independent Variables	RMSE	<i>p</i> -value
Faceville	IR (cm h ⁻¹)	None significant	na	na
	Ksat (15 cm) (cm h ⁻¹)	Bulk density	0.029	0.02
Orangeburg	IR (cm h ⁻¹)	Bulk density	7.09	0.10
	Ksat (15 cm) (cm h ⁻¹)	Soil strength	0.020	0.02
Lucy	IR (cm h ⁻¹)	Water dispersible clay	2.85	0.07
	Ksat (15 cm) (cm h ⁻¹)	Water dispersible clay	1.43	0.06

REFERENCES

Tugel, A.J., J.E. Herrick, J.R. Brown, M.J. Mausbach, W.Puckett, and K. Hipple. 2005. Soil change, soil survey, and natural resources decision making: a blueprint for action. Soil Sci. Soc. Am. J. 69:738-747.

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